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LEVEL II

Research Memorandum 68-3

SIGNAL GENERALIZATION AND DISCRIMINATION IN METER-MONITORING PERFORMANCE

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6 SIGNAL GENERALIZATION AND DISCRIMINATION
IN METER-MONITORING PERFORMANCE .

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AUTHOR'S NOTE

Signal generalization and discrimination have yet to be fully examined as factors in the monitoring of signal displays. A preliminary effort in this direction was initiated within BESRL's Monitor Performance Task and then prematurely terminated by the press of other requirements. The work that was done is described in the present memorandum, which is intended primarily for research workers in monitor performance who may wish to carry the experimentation forward or in some other way make use of the data or methodology.

Taken in toto, data from research on monitoring performance are a puzzle. Despite a burgeoning literature, there are discrepant findings among many studies, and there is need for concerted effort to pinpoint the sources of difference. The sources may well reside in something about apparatus, preparation or motivation of the subjects for the experiments, instructions, or procedures. Hopefully, an investigator with a searching eye may even find some useful clues in the present study! With this in mind, the writer has provided far more detail than would ordinarily be included in a preliminary report of this type.

Michael Kaplan

SUMMARY

Four enlisted men, observing deflections of the pointer in a null meter, served as subjects in a preliminary experiment to determine whether degree of disparity between critical and non-critical pointer positions can influence measures of monitoring performance during three-hour duty sessions.

At each of these sessions, ten in all, only one of five disparity conditions was presented. Each was replicated once, and the order of presentation was varied among subjects. Disparities, specified in chord lengths of the arcs they described, ranged from 0.7 through 2.8 millimeters. Pointer deflections, regarded as signals, were presented aperiodically with inter-signal intervals ranging from 15 through 240 seconds and averaging 93 seconds.

Performance following critical signal presentations was labeled S^+-responding. Performance following non-critical signal presentations was labeled S^--responding. Correct responding was achieved by pressing the button appropriate to the class of signal presented, within five seconds of the onset of the signal.

The data, it was felt, justified further and more extensive study of disparity and other generalization-discrimination variables in monitoring contexts. These results included:

1. When only critical signals were presented, as compared with cases in which subjects were required to discriminate critical from non-critical signals, slightly superior performance was shown (1) by all subjects with respect to percent of total signals correctly detected and percent of seen signals correctly identified and (2) by three of the four subjects with respect to latency of the response.

2. When discrimination of critical from non-critical signals was required, smaller signal disparities tended to affect adversely (1) S^+-responding and S^--responding with respect to percent of total signals correctly detected in three of the four subjects and (2) S^--responding with respect to percent of seen signals correctly identified by all four subjects. The influence of disparity on S^--responding appeared to vary among subjects, depending on whether the non-critical pointer position was above or below the critical pointer position on the meter face.

3. The smallest of the non-critical pointer deflections from zero--an arc whose chord length was 0.7 millimeters--tended to affect S^--responding adversely in all four subjects with respect to (1) percent of all signals evoking a response (whether or not correct) and (2) percent of total signals correctly detected.

Other observations were:

1. Latency of response, false alarms, and extra responding within the five-second response criterion latency were unaffected by signal disparity, although latency tended to be longer for the discrimination cases than for critical signals alone.

2. Classical performance decrement was not evident in any of the measures.

SIGNAL GENERALIZATION AND DISCRIMINATION IN METER-MONITORING PERFORMANCE

INTRODUCTION

In studies of monitoring performance (1,2), variables relating to the signal have received extensive treatment. Yet, in the same context, there has been virtually no experimental investigation of signal generalization and discrimination, an area in which problems may stem from physical similarity between critical and non-critical signals. A possible exception, albeit an indirect one, is Bakan's study (3) of difference thresholds for brightness. The present report describes an exploratory effort undertaken under a previous study by the Monitor Performance Task.[1] The general concern of studies in this series is identification of signal and response elements in monitoring tasks that make the tasks different--particularly along a difficulty dimension--and generate differential effects on performance.

Conceivably, when physical similarity between critical and non-critical signals increases, a monitoring task may increase in difficulty with a consequent increase in detection errors. On the other hand, some ancillary data (4) dealing with variety of stimulation imply that performance is poorer as discrimination requirements are simplified, particularly to the point of detecting the mere presence or absence of a signal.

Exploratory data bearing on these questions were sought in the behavior of monitoring a null meter. Throughout the experiment, a positive deflection of the pointer from center zero to a standard position served as the critical signal, S^+. In one phase, correct detection of S^+ occurrence was studied. This performance was compared with a discrimination phase, in which all other positive pointer positions were treated as non-critical signals, S^-, and disparity between S^+ and S^- positions was systematically varied. With two response buttons available, a right-hand press was the appropriate response to S^+ and a left-hand press was appropriate to S^-.

The experimental situation was thus reminiscent of the Donders b-reaction, a so-called disjunctive reaction in classical studies of reaction time (5,6), where longer reaction times were found with increasing similarity between alternative stimuli (7). This type of result could well be expected, too, in the signal detection setting.

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[1] Project b-23, "Effects of perceptual response complexity on performance in a visual monitoring task."

METHOD

SUBJECTS

Four enlisted men with normal vision served as subjects. Ranging in age from 20 to 25 years, none had had previous civilian or military experience in monitoring jobs, and all had Army General Technical (GT) Aptitude Area[a] scores of 100 or better.

APPARATUS

Signals. Each signal was provided through electrical activation of a 3-inch Weston model 1331[a] null type DC microammeter for 0.86 seconds. Nine pointer positions were generated by applying appropriate voltages. The pointer, which may be regarded as the radius of a circle, is 46 mm long. Its positions are defined here in terms of length of the chord intersecting the arc described by deflection of the pointer tip from zero. In millimeters of chord, the S^+ position was 3.5 and respective S^- positions were 0.7, 1.4, 2.1, 2.8, 4.2, 4.9, 5.6, and 6.3. Four S^- positions were thus below S^+ and four above, providing $S^+ - S^-$ disparities (differences in pointer position) of 0.7, 1.4, 2.1 and 2.8 mm. The meter was mounted on a vertical panel.

Response Buttons. A row of two pushbuttons separated by a distance of 2 1/2 inches was mounted on a vertical panel. Pressing the right-hand button within 5 seconds after signal presentation was the correct response to S^+. Pressing the left-hand button within the same response criterion latency was the correct response to S^-.

Monitor's Console. A monitor's console was located within a well-ventilated, sound attenuating chamber of the single-wall type manufactured by Industrial Acoustics Corporation.[a] The chamber, whose inside dimensions are 5 ft. wide by 6 1/2 ft. high by 8 ft. deep, was maintained between 74° and 76° F. and was illuminated from within by three 100-watt reflector lamps mounted on side walls and directed toward the ceiling. A one-way vision window in the chamber door permitted observation of the monitor and his console. The console is essentially a wide relay rack with a slide-out desk, whose depth can be adjusted by the monitor. Facing the monitor above the desk, whose upper edge is 30 inches above the floor, were 24 panels, each six inches by six inches, arranged in a four (column) by six (row) matrix. All panels were blank except three, which contained

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[a] Equally weighted composite of the Verbal and Arithmetic Reasoning tests of the Army Classification Battery.

[a] Identification of equipment by trade name is in the interest of precision in describing experimental procedure only and does not constitute indorsement by BESRL or the Department of the Army.

the meter, response buttons, and an intercom loudspeaker. Reading from bottom up and from left to right, the button panel was in row one, column four; the meter panel was in row three, column two; and the loudspeaker was in row four, column two.

Control and Recording Devices. A solid-state switching and signal generating device (8), fed by a punched paper-tape input containing the entire experimental program, was used to control presentation, sequence, and duration of signals along with inter-signal intervals. The device also stored frequency and temporal characteristics of subjects' responses and fed these data into a Hewlett-Packard model 560A[3] printer to provide a record in digital form.

Connections between this central control device and four test chambers with monitors' consoles permitted acquisition of data from four subjects simultaneously.

PROCEDURE

Experimental Conditions and Sessions. There were five experimental conditions. Under one of them, only S^+ was presented. Both S^+ and S^- were presented under the other four, which were the discrimination conditions involving disparities of 0.7, 1.4, 2.1, and 2.8 millimeters between S^+ and S^- pointer positions. Only one of the experimental conditions was presented at each session, and each subject was exposed to each of these conditions twice for a total of 10 sessions. The order of exposure differed for three of the four subjects and is shown for each of them in Table 1.

Table 1

ORDER OF EXPERIMENTAL CONDITIONS FOR EACH SUBJECT

Subject	Conditions[a]
0 - 1	2.8, 2.8, 1.4, 1.4, 0.7, 0.7, S^+, 2.1, S^+, 2.1
0 - 2	1.4, 1.4, 2.1, 2.1, 0.7, 0.7, S^+, S^+, 2.8, 2.8
0 - 3	2.1, 2.1, 2.8, 2.8, 1.4, 1.4, 0.7, 0.7, S^+, S^+
0 - 4	1.4, 1.4, 2.1, 2.1, 0.7, 0.7, S^+, S^+, 2.8, 2.8

[a] S^+ refers to the condition of S^+ alone. Numbers refer to disparity in millimeters between S^+ and S^- pointer positions during discrimination sessions.

[3] See footnote 3 on page 2.

Signal Presentation and Programs. Each experimental condition was characterized by a signal program presented according to the following arrangement: Each experimental session was divided into seven segments, each 25 minutes long. Sixteen signals were presented in each segment for a total of 112 per session. Under the S^+ alone condition, all signals were critical. Under the other conditions, involving S^+ - S^- discrimination, there were eight critical and eight non-critical signals per segment presented in random order. This order was different for each segment. At each of these discrimination sessions, the disparity between S^- and S^+ was constant, although the position of S^- was below S^+ four times and above it four times. The order of "belows" and "aboves" was randomized and was different for each segment.

Each segment began with an interval and ended with a signal. Inter-signal intervals per segment ranged from 15 through 240 seconds with an arithmetic mean of 93.25 seconds and a median of 90 seconds. The frequency distribution of these intervals is shown in Table 2. The sequence of intervals was randomized and was different for each segment.

With respect to inter-signal intervals and S^+ - S^- sequences, the overall order of presentation from segment to segment was repeated at each session.

Table 2

FREQUENCY DISTRIBUTION OF INTER-SIGNAL INTERVALS FOR EACH SEGMENT

Inter-Signal Interval	Frequency
15 (seconds)	2
20	2
52	1
60	1
80	1
90	3
120	2
150	2
180	1
240	1

Introducing Subjects to the Experiment. Upon reporting for duty, the subjects signed in at the adjutant's office and proceeded to the briefing room of the laboratory. There, they were first welcomed to the installation by the Executive Officer, who emphasized that the Army regarded the project and their participation as important to its mission. The subjects then filled out short personal data forms for the experimenter, after which he briefed them on the significance of research on monitoring performance, pointing out the more dramatic problems dealing with the safety of the nation. No detailed information concerning the experiment was offered.

At this point, following a short break, subjects were introduced to their individual test booths and monitoring consoles. Instructions and a general statement about the experiment were read to them over an intercom system (Appendix C). This included demonstration of S^+ and a number of different positions of S^-. The experimenter then checked with each subject to see whether there were questions to be answered and whether the instructions were fully understood. If necessary, demonstrations of S^+ and several S^- positions were repeated. The experimental session then began.

Daily Regimen. On the remaining days of the experiment, subjects signed in at the adjutant's office in the morning and reported to the laboratory briefing room, where they surrendered their watches for the duration of the experimental session. After entering the test booths, they were informed via the intercom whether they would receive S^+ or both S^+ and S^-. The experimenter checked with subjects individually regarding possible questions, and then the session was run. Before subjects had their watches returned and were dismissed at the end of the session, they were each briefly interviewed by the experimenter to determine their reactions to the day's procedure.

RESULTS AND DISCUSSION

PERFORMANCE MEASURES

Since this study involved a two-response situation, the meter-monitoring data were viewed in terms of (1) responding to S^+ and (2) responding to S^-. Each class of behavior was characterized primarily by four major measures. In the listing which follows, *R* refers to the *first* right- or left-hand response occurring *within the criterion latency* and *S* to signals of either type:

1. Percent of all *S* evoking a response: 100 (total number of *R* of both types) / (total number of *S*). Whether or not a response was correct, if a subject responded, it is likely that he had at least *seen* the signal. Hence, this measure gives an indication of degree of attention to the visual display.

2. Percent of total S correctly detected: 100 (number of correct R) / (total number of S presented). This measure reflects both failure to respond and incorrect responding. It might well be the most important measure for the field commander.

3. Percent of seen S correctly identified: 100 (number of correct R) / (total number of R). Since occurrence of a response indicates a signal has been seen, this measure reflects how well the subject discriminated S^+ from S^-, when he responded to signals.

4. Latency of the response: time in seconds from onset of S to occurrence of R. This measure indicates speed of response.

The first three measures are percentage scores. Several ancillary measures were also computed.

For the most part, the four subjects showed high performance levels. Any effects generated by the presumptive variables studied were small in magnitude.

SIGNAL VERSUS NO SIGNAL

When only S^+ was presented, there were indications of slight superiority in performance as compared with sessions in which subjects were required to discriminate S^+ from S^-. One might speculate that this tendency, as well as others described below, might have been more pronounced under a lower rate of signal presentation.

For each subject, each of the four performance measures has been averaged over the two sessions of S^+ alone and over all the discrimination sessions, both for responses to S^+ and responses to S^-. These values are shown for each subject in the sets of bar graphs in Figure 1, which is derived from data listed in Table 3 and the tables of Appendix A. The exceptions to the slight superiority tendency are seen in one subject with respect to latency and in two subjects with respect to percent of all signals evoking a response. Since the latter measure provides some indication of relative attention to the display, it would appear that, among the subjects in this study, attention was not affected by increasing the signal discrimination requirement. This procedure might be regarded as tantamount to McGrath's (4) increase in "variety of stimulation." Unlike his findings, in this case the increase did not lead to improved performance (note again results given in Figure 1 for all subjects for percent of total signals correctly detected and percent of seen signals correctly identified).

SIGNAL DISCRIMINATION

If signal disparity, as specified herein, is a variable influencing performance, any adverse affects might be expected to be more apparent

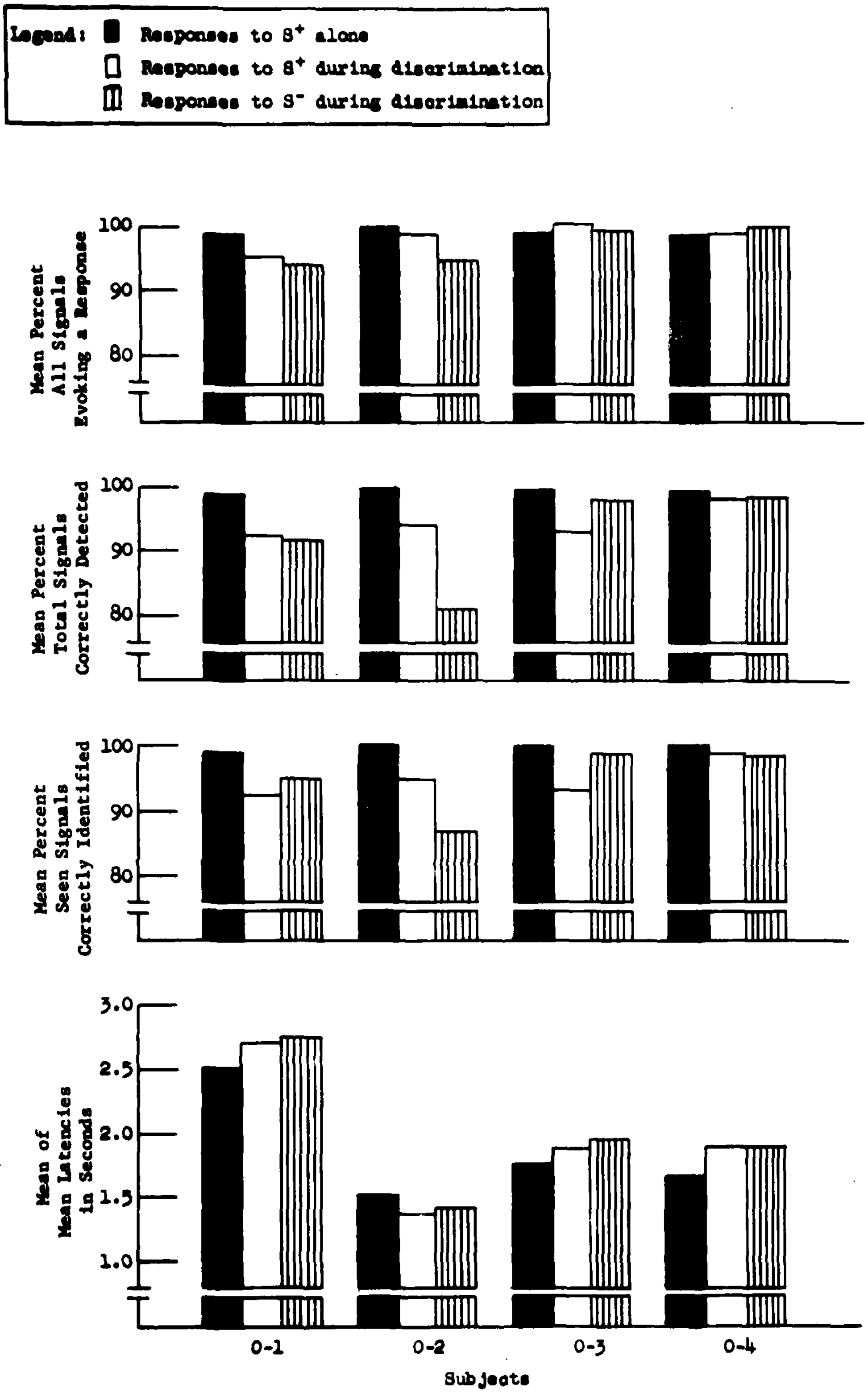


Figure 1. Bar graphs for individual subjects comparing responses to critical signal alone with responses discriminating critical from non-critical signals

for the smaller disparities between S^+ and S^- positions. In the case of 2.8-millimeter disparity, however, the possibility of an adverse effect might be stronger than would be expected, since one-half the S^- positions, while separated from the S^+ position by 2.8 millimeters, involved deflections of only 0.7 millimeters from zero. Such signals might easily be missed.

These tendencies do appear in varying degree in the percentage measures. Each of these, averaged for the two sessions, is plotted as a function of disparity between pointer positions for each of the subjects in Figures 2a, 2b, 2c, and 2d. Values for S^+ alone are also shown, revealing again some slight indications of better performance.

Looking at percent of all signals evoking a response (regardless of whether it was correct), it can be seen that attention to the meter display was good. Generally, all subjects responded to high proportions of signals, with an overall picture of unsystematic occasional failures. However, many of the smallest non-critical pointer deflections from zero were missed; at the 2.8-millimeter disparity, S^--responding did dip for all subjects.

With respect to percent of total signals correctly detected, this measure also reflected the same missed signals, with S^--responding again dipping for all subjects at the 2.8-millimeter disparity. In addition, three of the four subjects (0-1 is the exception) yielded curves showing an effect of disparity as a variable on both S^+-responding and S^--responding.

A similar effect is evident for all four subjects in the case of S^--responding for percent of seen signals correctly identified. This observation is particularly noteworthy from the standpoint of signal generalization and discrimination, since, of all the percentage measures, this one, by excluding missed signals, provides the most accurate behavioral reflection of the discrimination of S^+ from S^-. Only two of the subjects showed the disparity effect in the case of S^+-responding for this measure, and it is not clear why the effect was less pronounced here than for S^--responding.

The effect of signal disparity appears to show up more strongly and with an unexpected property in a finer-grained analysis of the S^- data. When the percentage measures for S^--responding are plotted as a function of pointer position (as in Figure 2), it appears that the influence of disparity may depend on whether the S^- deflection is above or below the S^+ position. In these plots, which show the curves for the two sessions separately and which appear as Figures 3a, 3b, 3c, and 3d, the vertical line represents the position of S^+ along the continuum of pointer positions on the meter face. (The S^- plots of Figure 2 could be obtained by "folding over" the figures at this point and averaging the resulting superimposed curves.)

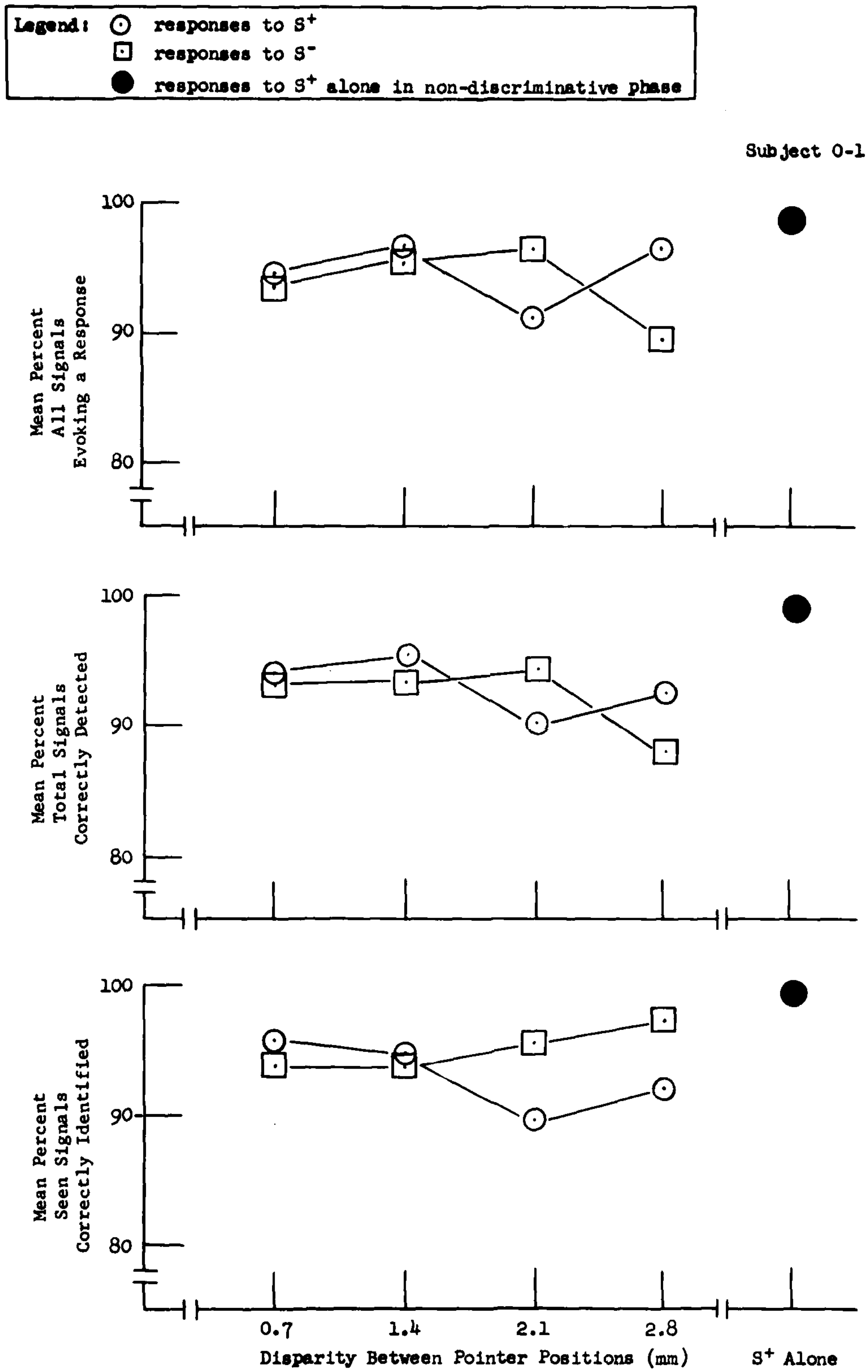


Figure 2a. Relationship between performance measures and signal disparity for Subject 0-1

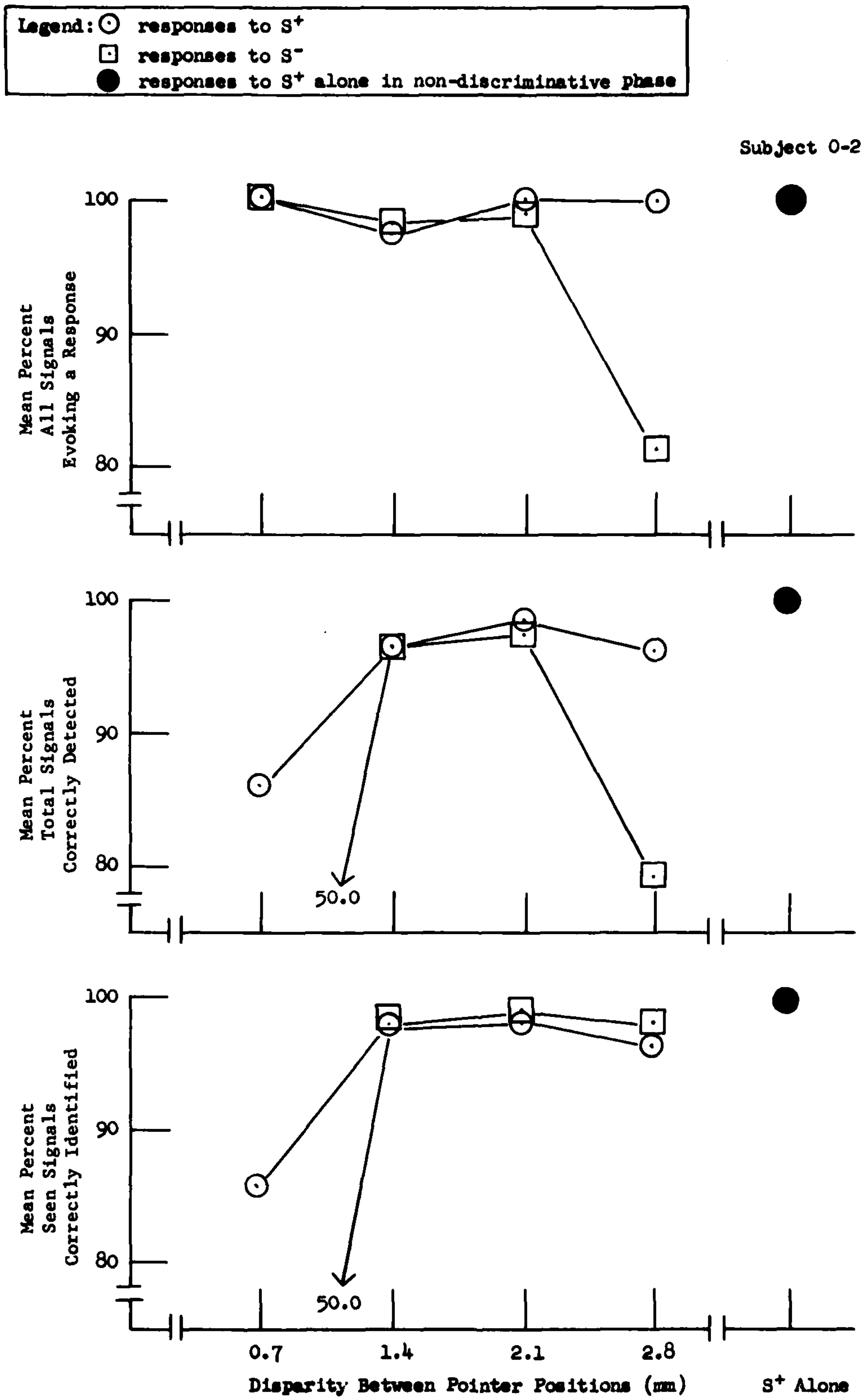


Figure 2b. Relationship between performance measures and signal disparity for Subject 0-2

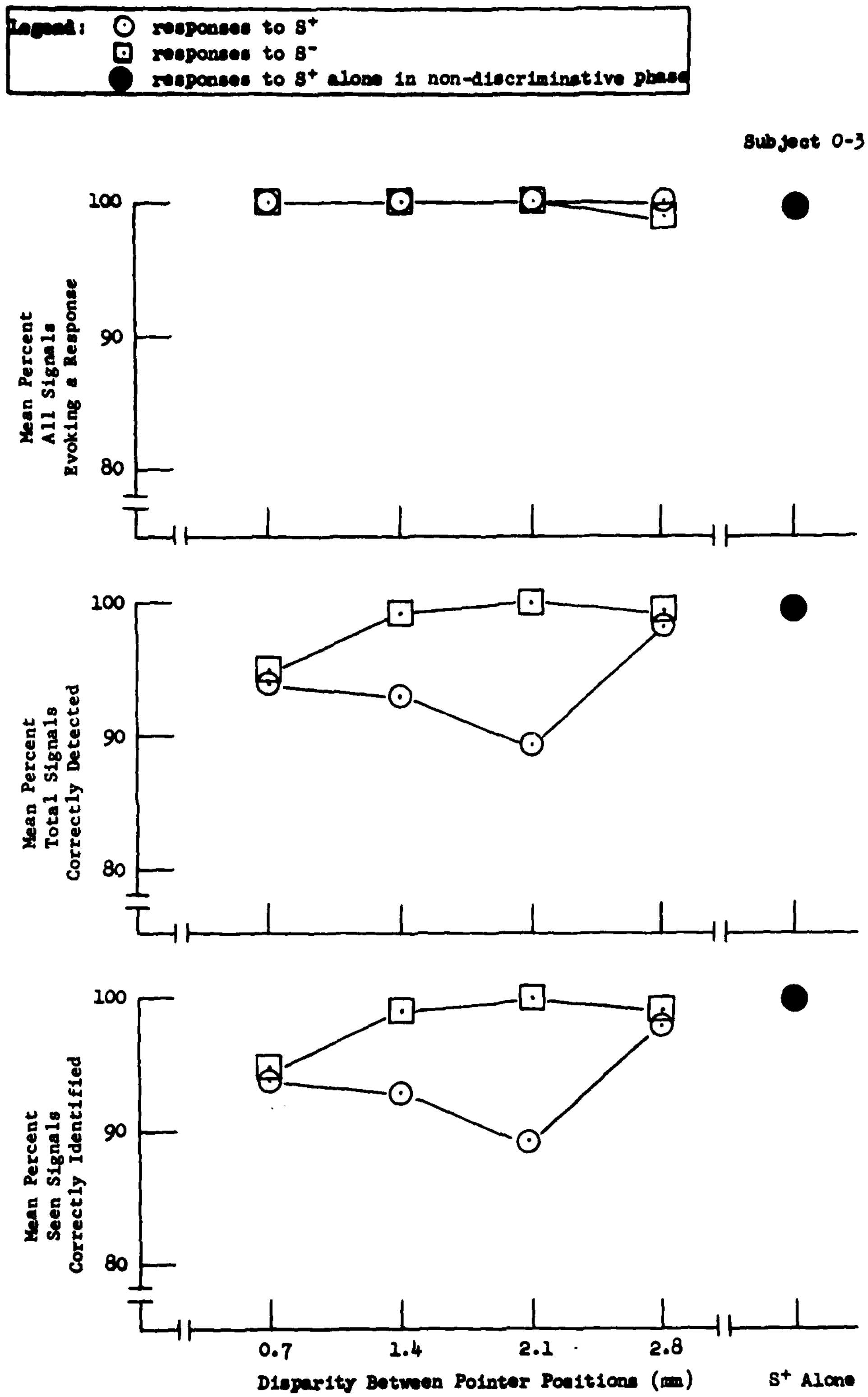
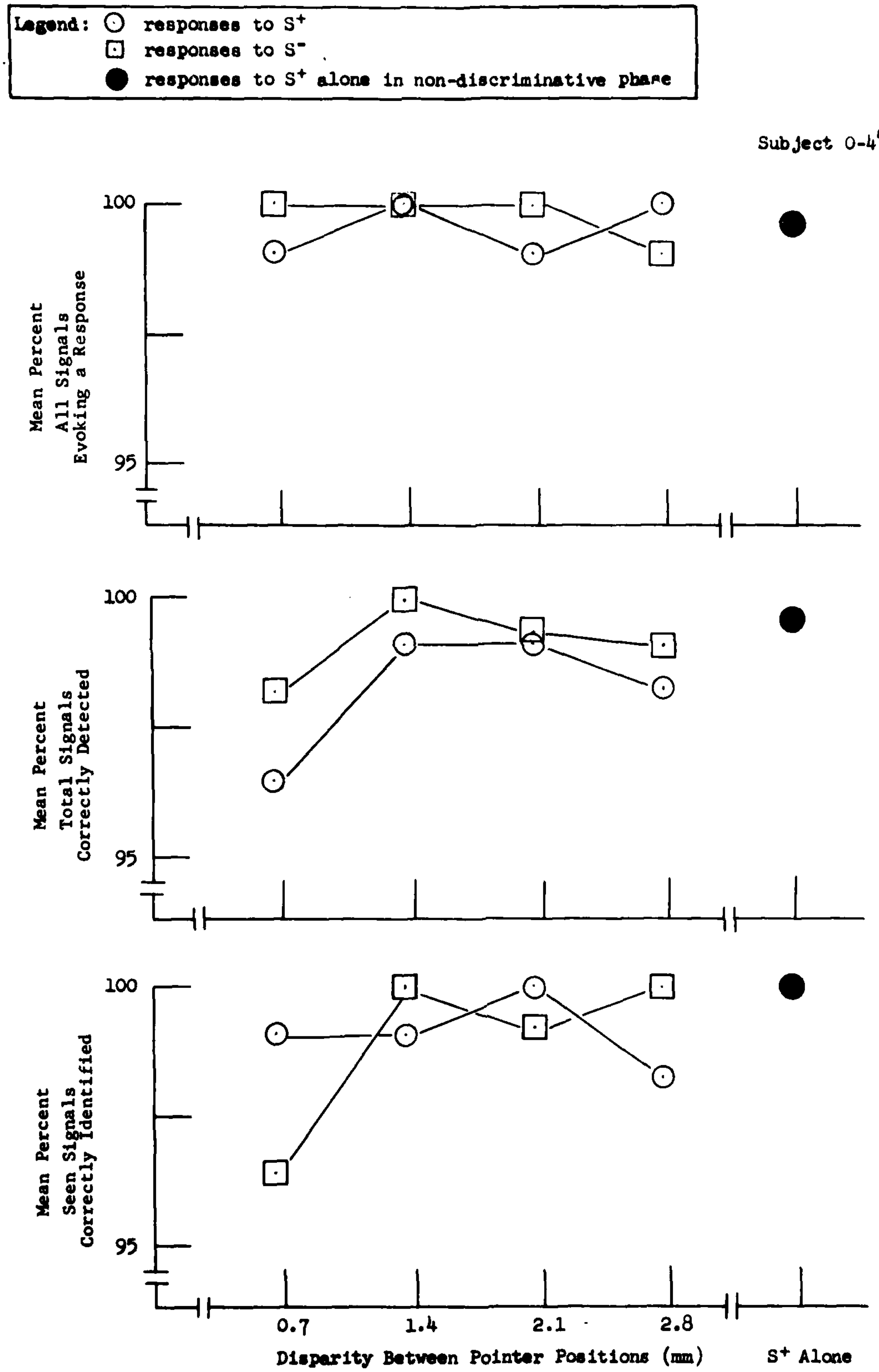


Figure 2c. Relationship between perfo-mance measures and signal disparity for Subject 0-3



[a] For subject 0-4, whose high-level performance showed variation within a narrow range, vertical scale has been expanded.

Figure 2d. Relationship between performance measures and signal disparity for Subject 0-4

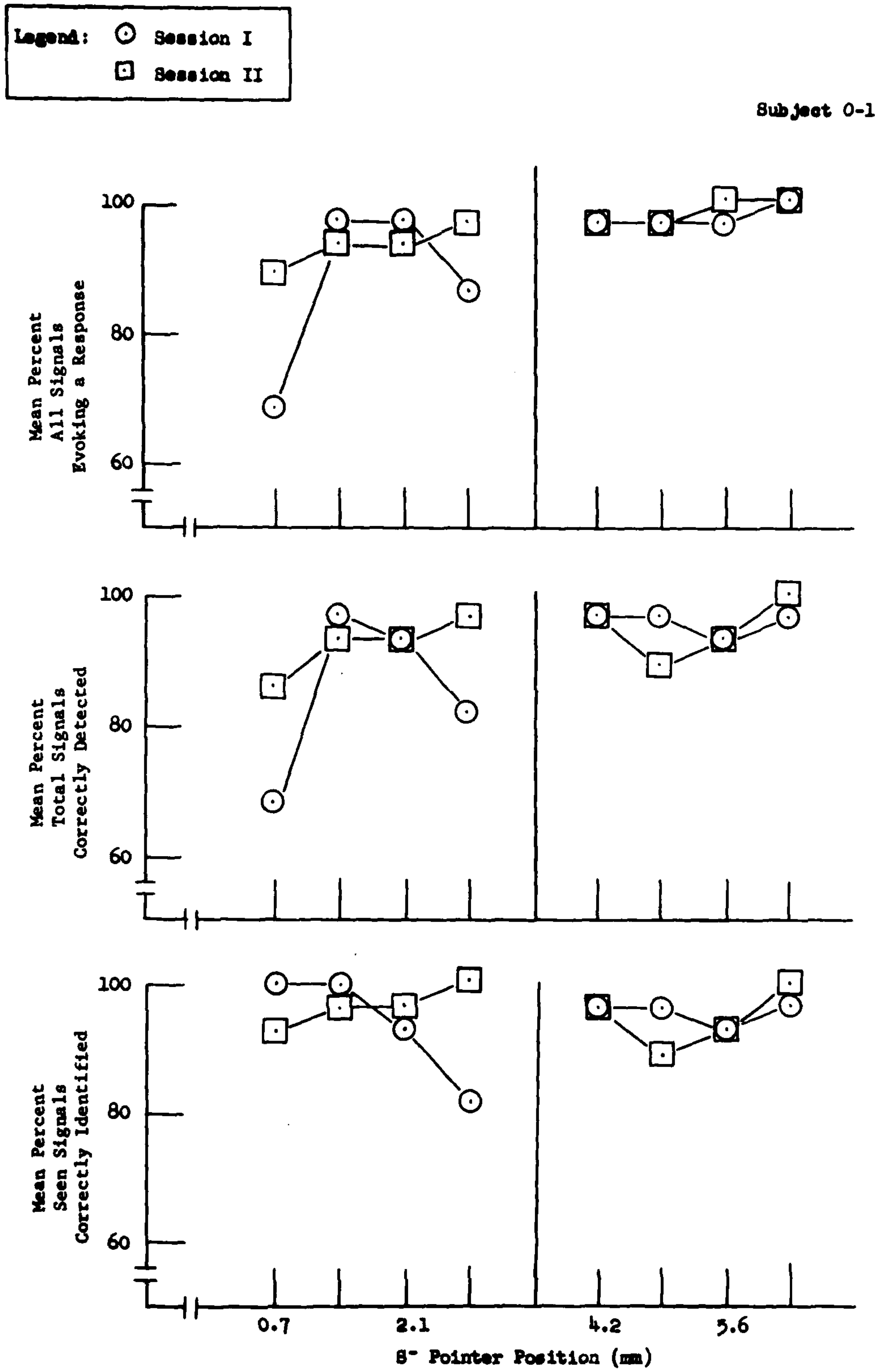


Figure 3a. Relationship between performance and signal disparity for Subject O-1 in Sessions I and II

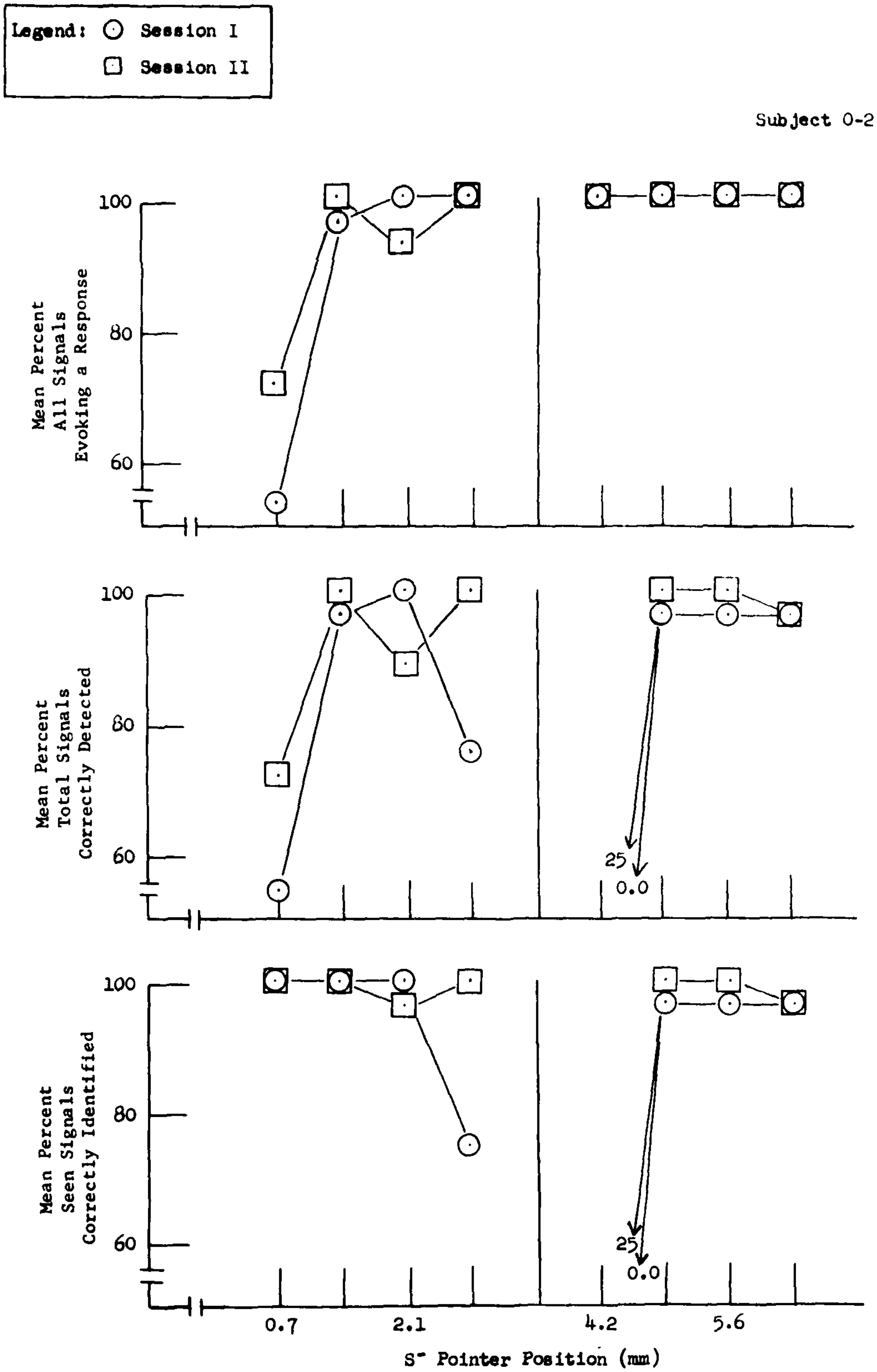
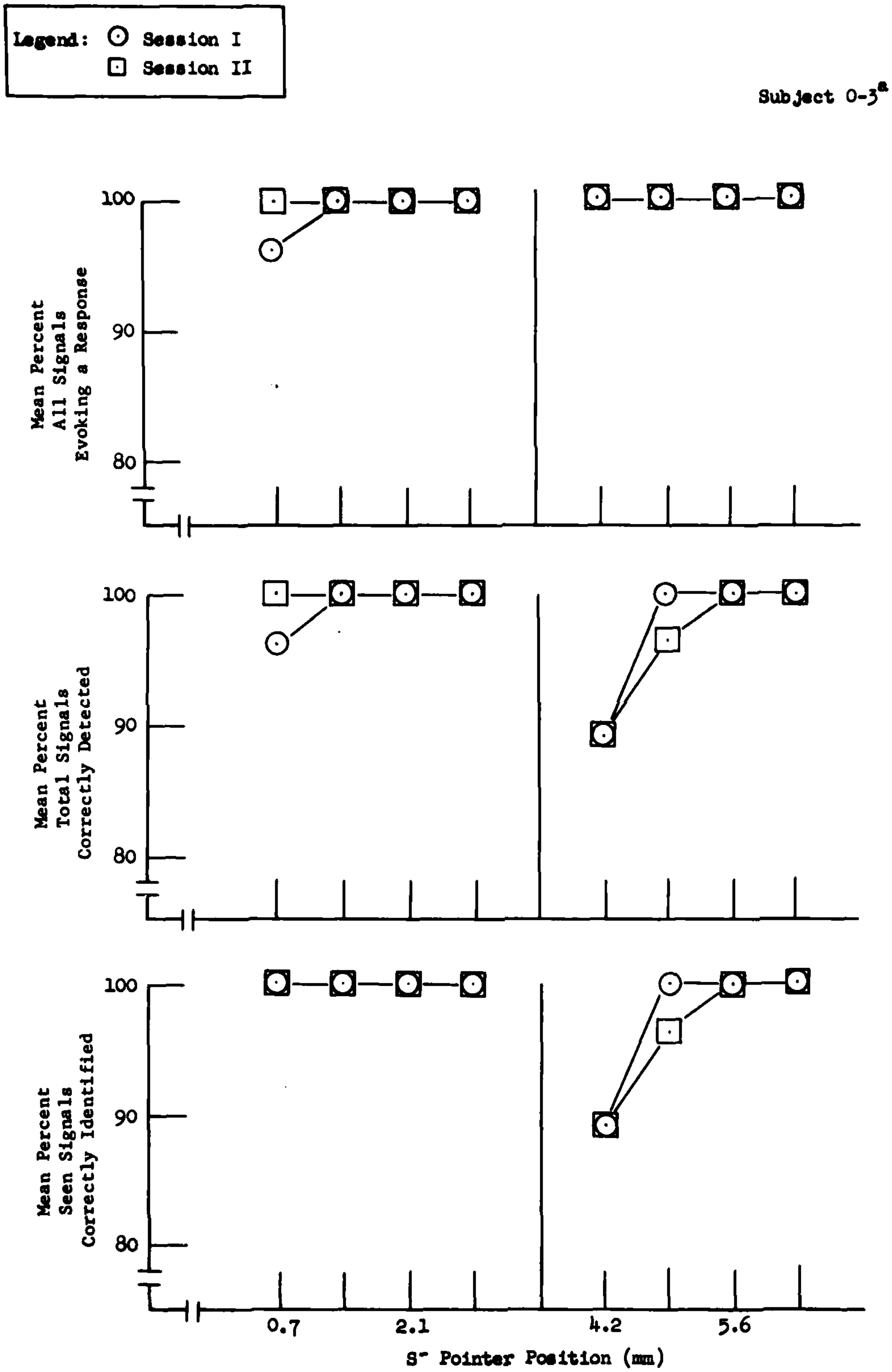
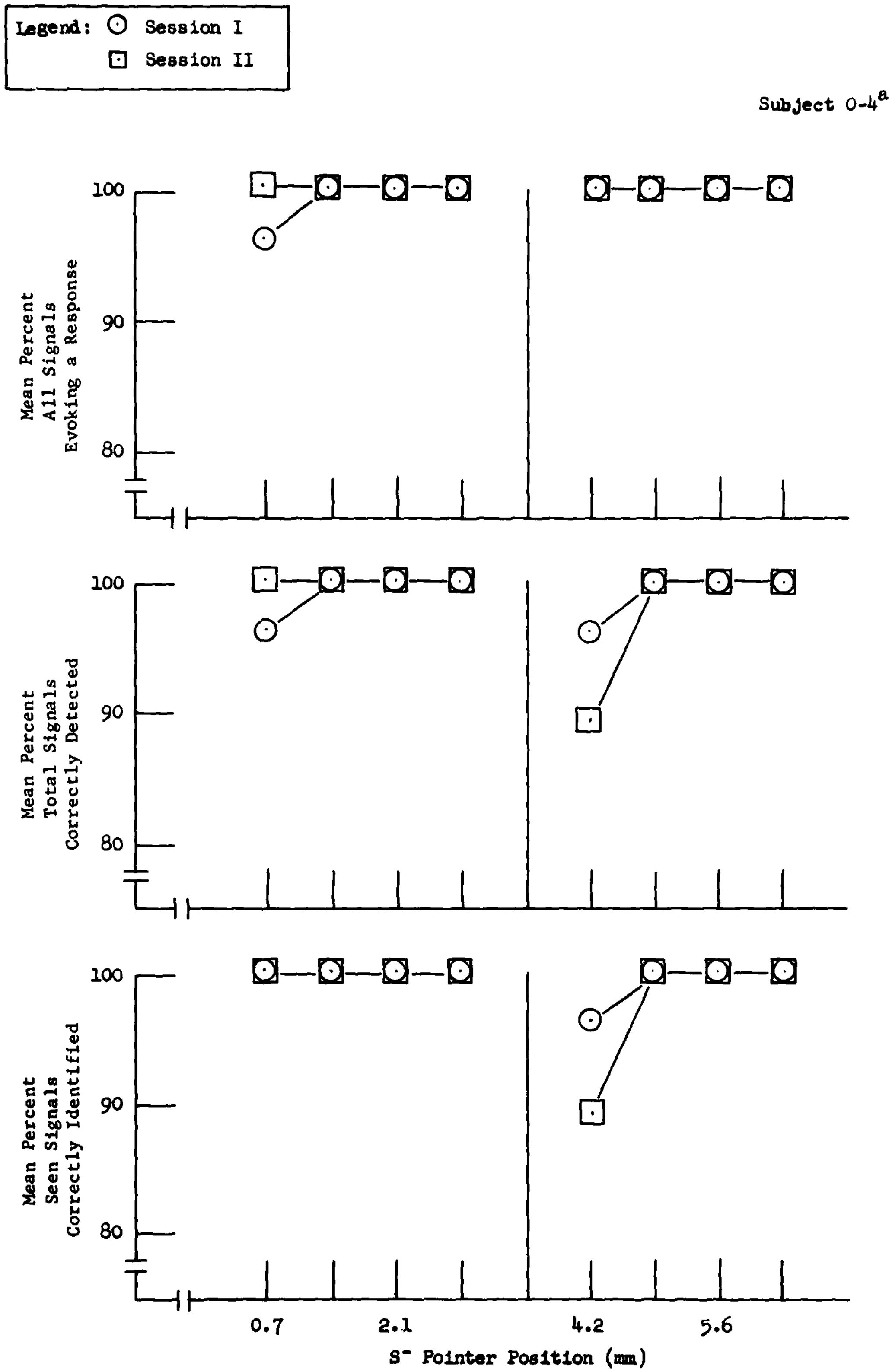


Figure 3b. Relationship between performance and signal disparity for Subject 0-2 in Sessions I and II



[a]For subjects 0-3 and 0-4, whose performance varied within a narrow range, the vertical scale has been expanded.

Figure 3c. Relationship between performance and signal disparity for Subject 0-3 in Sessions I and II



[a]For subjects 0-3 and 0-4, whose performance varied within a narrow range, the vertical scale has been expanded.

Figure 3d. Relationship between performance and signal disparity for Subject 0-4 in Sessions I and II

Subject 0-1 showed the disparity effect for positions below S^+ during the first session, but not during session two. The other three subjects showed this influence for "above" positions at both sessions, and 0-2 for "below" positions at session one as well. Conceivably, these observations might be accounted for in terms of the angle of regard with which subjects viewed the meter. They could thus be related to current efforts by Tiedemann (9) to limit the possible influence of parallax in certain types of monitoring situations.

All subjects showed some decrement at the 0.7 millimeter deflection from zero.

Tables from which Figures 2 and 3 were derived appear in Appendix A and B respectively.

Unlike the percentage measures, the latency data do not appear to have been influenced in any systematic manner by signal disparity. Latencies of correct responses both to S^+ and to S^- were averaged for each segment and the mean of these averages computed for each experimental condition. The results for each subject at each session appear in Table 3 and are at variance with findings from classical reaction time experiments (7) and from psychophysical studies of stimulus disparity that showed latency to be more sensitive than frequency-of-judgment measures (10). In the present case, however, subjects were not instructed to respond as rapidly as possible, nor were they given the classical ready signal.

Latencies for subject 0-1 were characteristically longer than for the other three subjects (see Figure 1). As previously noted (see Figures 3a and 3b), some data for this subject--and, to a lesser extent, for 0-2--appeared to reflect a session effect. The relevant tables, however, do not reveal a systematic influence for the session variable, nor any marked overall difference between S^+-responding and S^--responding, apart from the results on disparity versus percent of seen signals correctly identified.

FALSE ALARMS

Responding in the absence of a signal--so-called false alarms--was minimal and was not related to signal disparity. The highest frequency of this behavior was manifested by subject 0-1 during the 10-second interval beyond the 5-second criterion latency, i.e., between 5 and 15 seconds. False alarms occurring beyond 15 seconds were very rare. These data are summarized in Tables 4 and 5.

Table 3

MEAN OF MEAN LATENCIES AS A FUNCTION OF SIGNAL DISPARITY
WITH TYPE OF SIGNAL AS A PARAMETER

		Signal Disparities in Millimeters								
			S^+				S^-			
Subject	Session	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
O-1	I	2.45	2.79	2.42	2.69	2.71	2.86	2.52	2.79	2.72
	II	2.58	2.69	2.71	2.94	2.51	2.78	2.75	2.84	2.57
	Mean	2.52	2.74	2.56	2.82	2.61	2.82	2.64	2.82	2.64
O-2	I	1.50	1.12	1.26	1.43	1.54	1.22	1.29	1.38	1.60
	II	1.53	1.62	1.18	1.11	1.57	1.60	1.17	1.06	1.62
	Mean	1.52	1.37	1.22	1.27	1.56	1.41	1.23	1.22	1.61
O-3	I	1.70	2.05	2.06	1.85	1.89	2.17	1.94	1.87	1.94
	II	1.80	1.88	1.81	1.94	1.79	2.01	1.83	1.93	1.90
	Mean	1.75	1.96	1.94	1.90	1.84	2.09	1.88	1.90	1.92
O-4	I	1.55	1.81	2.20	1.90	1.71	1.94	2.09	1.81	1.80
	II	1.71	1.80	2.00	1.93	1.82	1.84	1.93	1.86	1.72
	Mean	1.63	1.80	2.10	1.92	1.76	1.89	2.01	1.84	1.76

Table 4

MEAN NUMBER OF FALSE ALARMS OCCURRING 5 THROUGH 15 SECONDS AFTER SIGNAL ONSET AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

Subject	Signal Disparities in Millimeters								
		S^+				S^-			
	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
0-1	1.0	2.0	2.5	4.0	1.5	2.5	2.0	1.0	0.5
0-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0-3	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5

MEAN NUMBER OF FALSE ALARMS OCCURRING AFTER 15 SECONDS FROM SIGNAL ONSET AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

Subject	Signal Disparities in Millimeters								
		S^+				S^-			
	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
0-1	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
0-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXTRA RESPONSES

When a subject responded more than once within the 5-second criterion latency following signal presentation, his behavior was labeled "extra responding." As Table 6 shows, very little of it appeared.

Table 6

MEAN NUMBER OF EXTRA RESPONSES WITHIN 5-SECOND CRITERION LATENCY AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

	Signal Disparities in Millimeters								
		S^+				S^-			
Subject	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
O-1	0.5	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.0
O-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
O-3	1.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	1.5
O-4	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0

PERFORMANCE DECREMENT

The longer a monitor observes a display, the poorer his signal detection is likely to be. This is the tendency classically reported in accounts of monitoring studies, and Mackworth (11), in her review of data bearing on these performance decrements, argued, in effect, that the relationship is an exponential function. It may be stated as

$$P = e^{(at^{\frac{1}{2}} + b)}$$

where P is a measure of performance, t is duration of observation, e is the base of natural logarithms, and a and b are constants. For percentage measures of P, the slope is negative.

From inspection of Tables 7, 8, 9, and 10, it is patent that the present data, when viewed as a function of time, are not properly described by such a relationship. For each of the four main measures, each subject's average value for both S^+- and S^--responding over sessions I and II was computed for successive 25-minute time segments under each of the signal conditions. Group medians ($N = 4$) of these values appear in the body of each table.

In several instances, these group medians suggest a possible decremental trend, viz., S^--responding at 0.7 mm disparity in Tables 8, 9, and 10 and at 2.8 mm disparity in Table 10; S^+-responding at 1.4 mm disparity in Table 9 and at 0.7 mm disparity in Table 10. However, the individual curves (not shown here) from which these group medians were derived reveal no consistent decline from subject to subject.

Table 7

GROUP MEDIAN PERCENT OF ALL SIGNALS EVOKING A RESPONSE AS A FUNCTION OF TIME WITH SIGNAL DISPARITY AND TYPE AS PARAMETERS

Signal Disparity (in mm)	Signal Type	25-Minute Segments						
		1	2	3	4	5	6	7
0.7	S^+	100.00	100.00	100.00	100.00	96.88	100.00	100.00
0.7	S^-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1.4	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1.4	S^-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.1	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.1	S^-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.8	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.8	S^-	90.62	93.75	90.62	93.75	96.88	96.88	96.88
S^+ only	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 8

GROUP MEDIAN PERCENT OF TOTAL SIGNALS CORRECTLY DETECTED AS A FUNCTION OF TIME WITH SIGNAL DISPARITY AND TYPE AS PARAMETERS

Signal Disparity (in mm)	Signal Type	25-Minute Segments						
		1	2	3	4	5	6	7
0.7	S^+	93.75	97.37	93.75	90.62	90.62	97.37	90.62
0.7	S^-	100.00	93.75	97.37	84.37	93.75	87.45	100.00
1.4	S^+	100.00	100.00	100.00	96.88	96.88	100.00	93.75
1.4	S^-	96.88	100.00	100.00	100.00	100.00	96.88	100.00
2.1	S^+	93.75	93.75	96.88	100.00	96.88	93.75	93.75
2.1	S^-	100.00	100.00	97.22	100.00	96.88	100.00	100.00
2.8	S^+	93.75	100.00	96.88	96.88	100.00	100.00	100.00
2.8	S^-	90.62	93.75	90.62	90.62	96.88	96.88	96.88
S^+ only	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 9

GROUP MEDIAN PERCENT OF SEEN SIGNALS CORRECTLY IDENTIFIED AS A FUNCTION OF TIME WITH SIGNAL DISPARITY AND TYPE AS PARAMETERS

Signal Disparity (in mm)	Signal Type	25-Minute Segments						
		1	2	3	4	5	6	7
0.7	S^+	93.75	96.88	96.88	90.62	93.75	96.88	96.88
0.7	S^-	100.00	93.75	96.88	84.37	90.62	90.62	93.75
1.4	S^+	100.00	100.00	100.00	96.88	96.88	100.00	93.75
1.4	S^-	96.88	100.00	100.00	100.00	100.00	96.88	100.00
2.1	S^+	96.88	93.75	96.88	100.00	96.88	93.75	93.75
2.1	S^-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.8	S^+	93.75	100.00	100.00	93.75	100.00	100.00	100.00
2.8	S^-	100.00	96.88	100.00	100.00	100.00	96.88	100.00
S^+ only	S^+	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 10

GROUP MEDIAN OF MEAN LATENCIES AS A FUNCTION OF TIME WITH SIGNAL DISPARITY AND TYPE AS PARAMETERS

Signal Disparity (in mm)	Signal Type	25-Minute Segments						
		1	2	3	4	5	6	7
0.7	S^+	1.78	1.84	1.90	1.90	1.98	1.86	1.91
0.7	S^-	1.88	1.92	2.07	1.96	2.08	2.07	1.96
1.4	S^+	1.96	2.06	2.00	2.02	2.10	1.98	1.99
1.4	S^-	1.90	1.98	1.94	1.98	1.94	1.92	1.98
2.1	S^+	1.62	1.98	1.95	1.85	1.98	1.94	1.80
2.1	S^-	1.87	1.89	1.94	1.87	1.92	1.85	1.73
2.8	S^+	1.85	1.78	1.85	1.74	1.82	1.79	1.79
2.8	S^-	1.75	1.83	1.83	1.83	1.95	1.84	1.84
S^+ only	S^+	1.67	1.70	1.70	1.71	1.66	1.69	1.68

Turning toward the data for S^+ alone, one is tempted to see support for Bakan's view (3) that if a "discrimination is made sufficiently easy, then there should be little or no decrement in frequency of response in the course of time." But, unless the most difficult discrimination case here is simply not difficult enough, the converse of Bakan's view is not evident. Whatever it is that causes errors and longer latencies to distribute themselves more frequently as a function of time was apparently not operative in the present study.

OTHER BEHAVIOR

From gross observation, all subjects appeared to take seriously their participation in the experiment. They cooperated fully, and when questioned about their reactions, expressed interest in how well they were doing. None was able to predict when or what type of signal would be presented, nor were reports consistent regarding differences in difficulty of sessions or judgments of elapsed time.

COMMENT

It can be argued that data from this study justify further experimentation with disparity as a variable. A case might also be made for more extensive investigation of the role of signal generalization and discrimination variables in monitoring situations. Answering a number of questions in this domain could well be useful. Some examples are:

1. Is generalization more likely and more resistant to breakdown with some types of signal than with others?

2. Is generalization in part a function of signal frequency and type of periodicity?

3. Can repeated monitoring sessions or discrimination-sharpening procedures reduce or eliminate generalization?

4. Is a given type of signal really a <u>complex of many specifiable properties</u>, each of which generalizes and/or exerts other kinds of stimulus control in varying amounts?

In connection with the last question, a further suggestion may not be out of place. The voluminous literature on monitoring behavior reveals great variety in the character of the event marking a signal as "critical"--apart from sense modality. This is an example of the lack of uniformity in apparatus and procedure that may account for discrepant findings among many studies. Such discrepancies in the present study have already been noted. It seems possible that a fresh look at the monitoring literature, a fresh effort to specify critical properties of the variables involved, and a subsequent recodification of findings may lead to more lawfulness than has heretofore been apparent.

In so doing, it may be desirable, as in the present study, to view monitoring behavior in terms of fundamental principles of psychology and to emphasize operationally specifiable controlling variables. The present effort, it is felt, provides another instance of the feasibility of such an approach.

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APPENDIX A

Tables Showing Percentage Measures as a Function of Signal Disparity With Type of Signal as a Parameter

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Table A-1

MEAN PERCENT OF SIGNALS EVOKING A RESPONSE AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

		Signal Disparities in Millimeters								
			S^+				S^-			
Subject	Session	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
0-1	I	100.00	91.07	100.00	96.43	94.64	91.07	96.43	96.43	83.93
	II	97.32	98.21	92.86	85.50	98.21	96.43	94.64	96.43	94.64
	Mean	98.66	94.64	96.43	90.96	96.43	93.75	95.54	96.43	89.28
0-2	I	100.00	100.00	100.00	100.00	100.00	100.00	100.00	98.22	76.78
	II	100.00	100.00	94.64	100.00	100.00	100.00	96.43	100.00	85.72
	Mean	100.00	100.00	97.32	100.00	100.00	100.00	98.22	99.11	81.25
0-3	I	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	98.22
	II	99.14	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Mean	99.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.11
0-4	I	99.11	98.21	100.00	100.00	100.00	100.00	100.00	100.00	98.22
	II	100.00	100.00	100.00	98.21	100.00	100.00	100.00	100.00	100.00
	Mean	99.56	99.10	100.00	99.10	100.00	100.00	100.00	100.00	99.11

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Table A-2

MEAN PERCENT OF TOTAL SIGNALS CORRECTLY DETECTED AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

		Signal Disparities in Millimeters								
			S^+				S^-			
Subject	Session	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
0-1	I	100.00	91.07	100.00	92.85	87.50	89.28	94.64	94.64	82.14
	II	97.32	96.42	89.28	85.71	96.42	96.42	91.07	92.85	92.85
	Mean	98.66	93.74	94.64	89.28	91.96	92.85	92.86	93.74	87.50
0-2	I	100.00	96.42	98.21	96.42	94.64	50.00	98.21	94.64	75.00
	II	100.00	75.00	94.64	100.00	98.21	50.00	94.64	100.00	83.92
	Mean	100.00	85.71	96.42	98.21	96.42	50.00	96.42	97.32	79.46
0-3	I	100.00	89.28	94.64	87.50	98.21	94.64	100.00	100.00	98.41
	II	99.14	98.21	91.07	91.07	98.21	94.64	98.21	100.00	100.00
	Mean	99.57	93.74	92.86	89.28	98.21	94.64	99.10	100.00	99.20
0-4	I	99.11	98.21	98.21	100.00	98.21	98.21	100.00	98.41	98.21
	II	100.00	94.64	100.00	98.21	98.21	98.21	100.00	100.00	100.00
	Mean	99.56	96.42	99.10	99.10	98.21	98.21	100.00	99.20	99.10

Table A-3

MEAN PERCENT OF SEEN SIGNALS CORRECTLY IDENTIFIED AS A FUNCTION OF SIGNAL DISPARITY WITH TYPE OF SIGNAL AS A PARAMETER

		Signal Disparities in Millimeters								
			S^+				S^-			
Subject	Session	S^+ only	0.7	1.4	2.1	2.8	0.7	1.4	2.1	2.8
0-1	I	100.00	92.86	100.00	92.86	87.50	89.28	94.64	96.17	97.96
	II	98.10	98.21	89.29	85.71	96.43	98.21	92.86	94.64	96.43
	Mean	99.05	95.54	94.64	89.28	91.96	93.74	93.75	95.40	97.20
0-2	I	100.00	96.42	98.21	96.42	94.64	50.00	98.21	98.21	98.21
	II	100.00	75.00	97.61	100.00	98.21	50.00	98.21	100.00	97.95
	Mean	100.00	85.71	97.91	98.21	96.42	50.00	98.21	99.10	98.08
0-3	I	100.00	89.28	94.64	87.50	98.21	94.64	100.00	100.00	98.41
	II	100.00	98.21	91.07	91.07	98.21	94.64	98.21	100.00	100.00
	Mean	100.00	93.74	92.86	89.28	98.21	94.64	99.10	100.00	99.20
0-4	I	100.00	100.00	98.21	100.00	98.21	98.21	100.00	98.41	100.00
	II	100.00	98.21	100.00	100.00	98.21	94.64	100.00	100.00	100.00
	Mean	100.00	99.10	99.10	100.00	98.21	96.42	100.00	99.20	100.00

APPENDIX B

Tables Showing Percentage Measures for Responses to Non-critical Signals as a Function of Pointer Position

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Table B-1

MEAN PERCENT OF NON-CRITICAL SIGNALS EVOKING A RESPONSE AS A FUNCTION OF POINTER POSITION

Subject	Session	S⁻ Pointer Position in Millimeters							
		0.7	1.4	2.1	2.8	4.2	4.9	5.6	6.3
0-1	I	67.86	96.43	96.43	85.71	96.43	96.43	96.43	100.00
	II	89.28	92.86	92.86	96.43	96.43	96.43	100.00	100.00
	Mean	78.57	94.64	94.64	91.07	96.43	96.43	98.22	100.00
0-2	I	53.57	96.43	100.00	100.00	100.00	100.00	100.00	100.00
	II	71.43	100.00	92.86	100.00	100.00	100.00	100.00	100.00
	Mean	62.50	98.22	96.43	100.00	100.00	100.00	100.00	100.00
0-3	I	96.43	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Mean	98.22	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0-4	I	96.43	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Mean	98.22	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table B-2

MEAN PERCENT OF TOTAL NON-CRITICAL SIGNALS CORRECTLY DETECTED AS A FUNCTION OF POINTER POSITION

Subject	Session	S⁻ Pointer Position in Millimeters							
		0.7	1.4	2.1	2.8	4.2	4.9	5.6	6.3
O-1	I	67.86	96.43	92.86	82.14	96.43	96.43	92.86	96.43
	II	85.71	92.86	92.86	96.43	96.43	89.29	92.86	100.00
	Mean	76.78	94.64	92.86	89.70	96.43	92.86	92.86	98.22
O-2	I	53.57	96.43	100.00	75.00	25.00	96.43	96.43	96.43
	II	71.43	100.00	89.29	100.00	00.00	100.00	100.00	96.43
	Mean	62.50	98.22	94.64	87.50	12.50	98.22	98.22	96.43
O-3	I	96.43	100.00	100.00	100.00	89.29	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	89.29	96.43	100.00	100.00
	Mean	98.22	100.00	100.00	100.00	89.29	98.22	100.00	100.00
O-4	I	96.43	100.00	100.00	100.00	96.42	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	89.28	100.00	100.00	100.00
	Mean	98.22	100.00	100.00	100.00	92.85	100.00	100.00	100.00

Table B-3

MEAN PERCENT OF SEEN NON-CRITICAL SIGNALS CORRECTLY IDENTIFIED AS A FUNCTION OF POINTER POSITION

Subject	Session	S⁻ Pointer Position in Millimeters							
		0.7	1.4	2.1	2.8	4.2	4.9	5.6	6.3
O-1	I	100.00	100.00	92.86	82.14	96.43	96.43	92.86	96.43
	II	92.86	96.43	96.43	100.00	96.43	89.29	92.86	100.00
	Mean	96.43	98.22	94.64	91.07	96.43	92.86	92.86	98.22
O-2	I	100.00	100.00	100.00	75.00	25.00	96.43	96.43	96.43
	II	100.00	100.00	96.43	100.00	00.00	100.00	100.00	96.43
	Mean	100.00	100.00	98.22	87.50	12.50	98.22	98.22	96.43
O-3	I	100.00	100.00	100.00	100.00	89.29	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	89.29	96.43	100.00	100.00
	Mean	100.00	100.00	100.00	100.00	89.29	98.22	100.00	100.00
O-4	I	100.00	100.00	100.00	100.00	96.42	100.00	100.00	100.00
	II	100.00	100.00	100.00	100.00	89.28	100.00	100.00	100.00
	Mean	100.00	100.00	100.00	100.00	92.85	100.00	100.00	100.00

APPENDIX C

INSTRUCTIONS TO SUBJECTS

INSTRUCTIONS

In this experiment, you will operate one component of an important piece of Army technical equipment. Equipment of this kind is often used in enemy warning systems. The purpose of this experiment is to find out how well this equipment works and how its operation may be improved.

Now, pay very close attention. You are seated at the Equipment Control Board. Look at the rectangular meter marked "Microamperes." Also look at the panel in the lower right-hand corner that contains the pushbuttons. You will be concerned only with the two buttons marked "Left" and "Right." Your job is to do three things:

First, keep watching the meter. Look for movements of the pointer. They will be rapid. Some of these movements are called "critical signals." Others are called "non-critical signals." We will show you the critical signals. We will also show you some of the non-critical signals.

Second, when you see the critical signals, press the button marked "Right."

Third, whenever you see any of the non-critical signals, press the button marked "Left." When you press either one of the buttons, be sure you press it hard until you hear a click.

We shall now demonstrate the critical signal and some of the non-critical signals. We also wish to check on your equipment. When you see a signal, please press the correct button just as you would during the experiment. During the first few demonstrations of the signals, the movements of the pointer will last longer than during the experiment.

(At this point, Signal Demonstration Tape is run and experimenter reads from the coordinated statements naming the signals on the tape. Then, the instructions are continued.)

Remember, when you see a critical signal, press "Right." When you see a non-critical signal, press "Left." However, at some sessions, you will be shown only critical signals. You will be informed at the beginning of each session whether to expect only critical or both critical and non-critical signals.

At each session, you must remain on duty for three hours. There will be no break. You will be told when the period begins and when it ends. Do not sleep. Do not touch the lights in your booth. You will be observed through the one-way vision window. You may smoke if you wish.

We are about to begin the experiment. Do you have any questions?

Please do the best job you can.

The experiment will now begin.

STATEMENTS COORDINATED WITH DEMONSTRATION SIGNALS

(1) This is the position of the critical signal. Press the button marked "Right."

(2) This signal is critical. Press "Right."

(3) This signal is non-critical. Press the button marked "Left."

(4) This signal is critical. Press "Right."

(5) This signal is non-critical. Press "Left."

(6) Non-critical. Press "Left."

(7) Critical. Press "Right."

(8) Non-critical. Press "Left."

From now on, the signals will be presented rapidly, just as you will see them in the experiment.

(9) Critical. Press "Right."

(10) Critical. Press "Right."

(11) Non-critical. Press "Left."

(12) Critical. Press "Right."

(13) Non-critical. Press "Left."

(14) Critical. Press "Right."